Steel Primer

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INDUSTRY PRIMER

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What Is Steel?

Steel is basically the end result of refined iron, typically including other elements or alloys to produce different types of steel for various applications. Standard carbon steel contains 97% iron and 0.05-1.25% carbon. Alloys, such as nickel, molybdenum, chromium, manganese, and silicon can be added to make steel stronger, malleable, and corrosion resistant, etc. Coating steel with zinc, aluminum, tin, terne, and/or paint further enhances the quality and appearance of certain types of steel.

Crude (raw) steel is the first solid state after melting and is suitable for further processing or sale. Raw steel is typically hard and brittle. Higher carbon content enhances the hardness of steel, but increases the brittleness as well. The high degree of brittleness is not a desirable property as far as industrial requirements are concerned. It is therefore alloyed with other metals, each of which imparts special properties to the steel.

The various types of steel (and alloys) with their properties and uses are highlighted in Exhibit 1.

Exhibit 1: Types of Steel

Type of Steel	Properties	Typical Applications
Carbon Steels		
Low-Carbon (0.07 – 0.25%)	Reduced hardness and brittleness, ease of cold-molding	Car bodies (doors, bonnets, etc)
Medium Carbon (0.25–0.5%)	Higher wear resistance	Rails and rail products: couplings, crank shafts, axles, gears, forgings
Carbon Tool Steel (0.85–1.2%)	Strength and wear resistance	Cutting tools, rails
Cast Iron (2.5 - 3.8%)	High degree of brittleness, ease of casting	Pistons and cylinders (dues to ease of casting)
Alloy Steels (specialized steel)		
Cobalt Steel	High magnetic permeability	Magnets
Manganese	Strength and hardness	Heavy duty rail crossings
Molybdenum	High strength even at high temperatures	High speed drill tips
Nickel and Chromium	Corrosion resistance	Surgical instruments
Titanium	Increased hardness and tensile strength	High speed tool steels, permanent magnets
Tungsten	High melting point and toughness	Cutting and drilling tools
Vanadium	Superior strength and hardness	Tools

Source: Credit Suisse.

How to Make Steel

Five Steps to Making Steel

(1) **Raw material treatment:** purifying coal into a high-carbon fuel called coke.

(2) **Iron Making:** burning coke in a blast furnace to melt iron ore. At the same time, using limestone to eliminate impurities in the ore, resulting in a high-iron-content product called pig iron.

(3) **Steel Making:** combining molten pig iron with steel scrap in a basic oxygen furnace to remove most of the remaining carbon from the pig iron, thus producing steel.

(4) **Casting:** casting the steel into a semi-finished shape.

(5) **Rolling and finishing:** rolling semi-finished products into a variety of finished shapes.

Two Production Processes

Production is primarily undertaken through two different processes:

(1) Integrated Steel Plants (ISPs)

(2) Electric Arc Furnaces (EAF's, typically known as mini-mills)

Steel can be made from iron ore or from recycled scrap steel.

Integrated steel mills use a method known as the basic oxygen furnace method (BOF) to produce steel, while mini-mills use the electric arc furnace method (EAF). The BOF method consumes metallurgical coal in the form of coke, whereas the EAF method employs electricity to remelt scrap steel as its primary feedstock to produce steel. Mini-mills do not consume metallurgical coal.

In an electric arc furnace, steel is made from using steel scrap in place of iron ore and by following steps 3-5, described above.

The iron making portion of the steel production process (i.e., step 2) is the most energy intensive. Therefore, steel produced via the mini-mill process, which does not use a basic oxygen furnace, generally is less energy and GHG (greenhouse gas) intensive than steel production from an integrated steel mill.

Normally, EAF's are smaller than BOF's and are characterized by higher productivity and lower overhead costs relative to BOF's. EAF's typically offer a higher degree of flexibility with regards to production levels when compared with BOF's. However, EAF production is highly dependant on the availability of scrap steel and electricity, as these two inputs typically account for 75%-plus of EAF's total operating costs. Therefore, the economic benefits of the EAF versus BOF production process are also dependent upon geographic location, with proximity to scrap steel and low cost electricity being important components. The United States is one of world's largest EAF steel producing countries due to an abundance of steel scrap and the availability of relatively inexpensive electricity.

The BOF method accounts for approximately 71% of global steel production, while the EAF method accounts for approximately 28% (the remaining 1% of steel output is produced using various other production methods). EAF's represent the fastest growing segment of steel production technology; increasing market share from approximately 15% to 28% during the past few decades.

Integrated steel mills historically produced a higher quality end product when compared with mini-mills, as the use of scrap steel in a mini-mill typically created certain imperfections/impurities not found in the integrated production process.

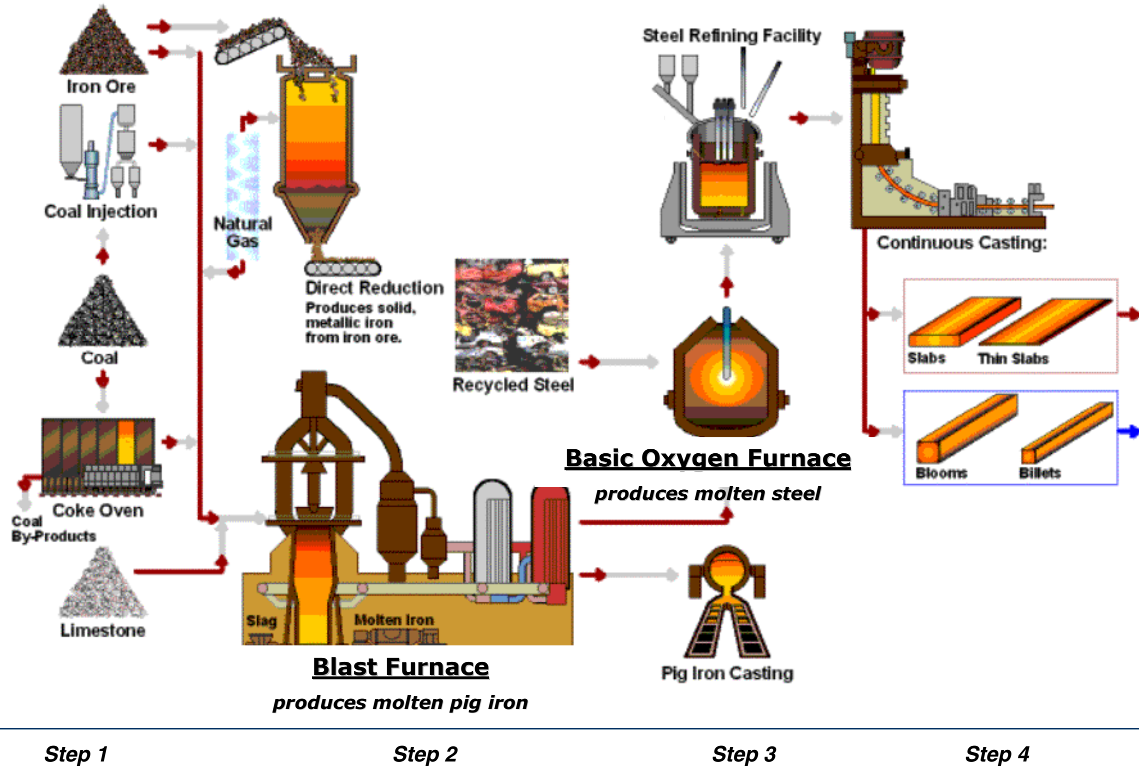
Historically, mini-mills typically used almost 100% scrap as input into the furnace, while the integrated producers typically used 10-25% scrap in the production process.

However, the growth of mini-mills caused an increase in global scrap prices, which in turn led to research for substitutes of scrap, mostly produced from virgin iron ore that could be used by mini-mills to produce a better steel quality. The most popular scrap substitutes are direct reduced iron (DRI), hot briquetted iron (HBI), and iron dynamics (IDI).

Scrap substitutes and technology improvements in the mini-mill production process have also improved the quality of finished steel product from EAF's, allowing mini-mills to become increasingly competitive with integrated producers at various points in the steel product value chain.

Steel Making Process

Exhibit 2: The Integrated Steel Making Process—Flow line (Steps 1-4)*



**Note: The mini-mill process essentially starts at Step 3 and replaces the BOF with an electric arc furnace.*

Source: American Iron and Steel Institute.

Step 1—The Raw Material Recipe

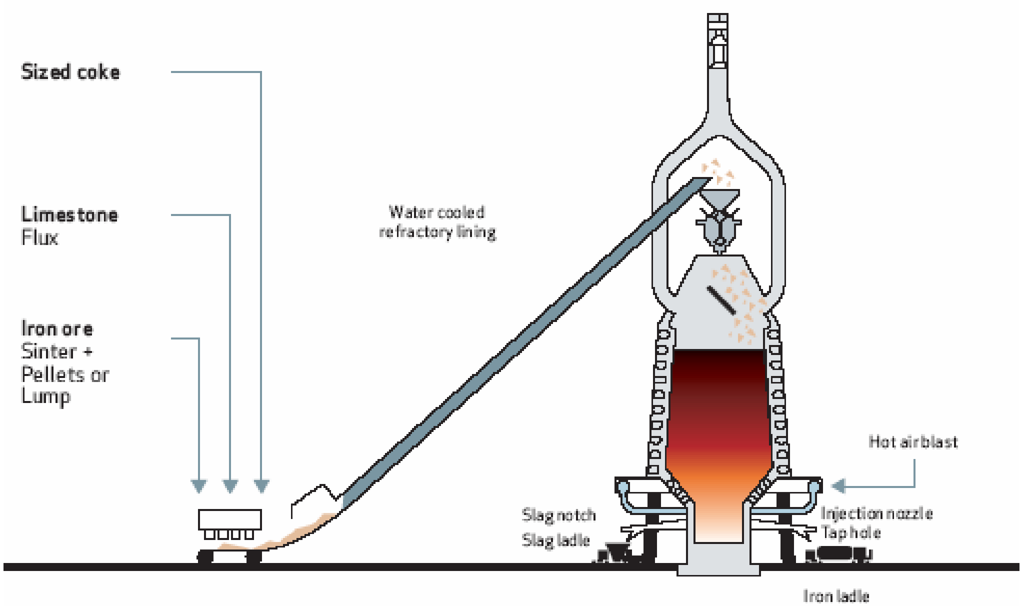
The raw materials used to make steel in the integrated production process are iron ore, metallurgical coal (in the semi-finished form of coke), and limestone.

- Mix 1¾ tons of iron ore, ¾ ton of coke, ¼ ton of limestone, and 4 tons of air to produce 1 ton of pig iron in a blast furnace.
- Iron ore typically has varied iron content and typically needs to be concentrated to 60-70% iron content through a process of crushing, roasting, magnetic separation, or chemical/gravitational flotation.
- To allow good airflow around the ore during the process of pig iron reduction in the blast furnace, iron ore is aggregated into pellets or briquettes before being used in steelmaking.
- To make coke, metallurgical coal is baked in coke ovens (i.e., a coke battery) at 1,650-2,000 degrees Fahrenheit to eliminate water and impurities, converting metallurgical coal into almost a pure carbon state. In the blast furnace, the ore is piled onto the coke. Therefore, the coke needs to be structurally strong to allow for appropriate air circulation after the ore burden is piled onto the coke.

Step 2—Iron Making in the Blast Furnace

- In the blast furnace, a continuous jet of preheated air is used to allow the coke to burn intensely at a temperature of about 3,500 degrees Fahrenheit. The intense heat breaks down the iron ore, and creates carbon monoxide. The carbon monoxide absorbs the oxygen contained in the iron oxide ore and transformed into carbon dioxide, which is then exhausted. The residual is pig iron, a form of purer iron in a liquid state that remains at the bottom of the furnace.

Exhibit 3: **Basic Oxygen Furnace**



Source: World Coal Institute.

- At the bottom of the blast furnace, the molten limestone attracts residual impurities in the cooking ore and floats them to the top of the bath of molten pig iron forming in the bottom of the furnace. This limestone layer is called slag, and attracts certain elements while repelling others as those elements precipitate out of the molten solution.

- When a considerable quantity of molten pig iron has accumulated at the bottom of the blast furnace, a tap hole is opened and the pig iron is poured into vessels for further processing, while the slag follows a different route for other markets.

Step 3—Steel Making in the BOF or EAF

Basic Oxygen Furnace

- In the traditional way of making steel (integrated route), pig iron containing 3-4% carbon is refined further to make steel. Typically molten pig iron is poured into a Basic Oxygen Furnace (BOF), where the carbon content is reduced to approximately 0.5-1.25% by adding limestone (to remove impurities). Scrap steel is also added to serve as a coolant.

- In a BOF, oxygen is blown at speeds of up to Mach 2.3 through a long tube inserted into the furnace. Upon oxidization of carbon and silicon in the mixture, a very high heat is released, and the scrap steel melts into the molten mass. The oxygen serves to remove the carbon.

- After oxygen is blown into the BOF for about 20 minutes, slag is poured off the top of the molten bath in one direction, and the steel is poured in the other direction onto a huge ladle where the chemistry and quality of steel is controlled with more accuracy.

- A number of variations/adjustments have been applied to the basic oxygen furnace process. Examples include using pulverized coal injection (PCI) as a substitute for more expensive, higher quality, metallurgical coals in the coke making process. Adjusting how much scrap is used, how material is charged into the furnace, etc., can all be made to enhance efficiencies and/or to mitigate energy costs in a weak market, or conversely refining the process to produce more steel (albeit slightly more expensive) in a strong market.

Electric Arc Furnace

- The mini-mill process essentially eliminates steps 1-2, and in step 3, an electric arc furnace replaces a basic oxygen furnace. An electric arc furnace does not use hot metal, but instead is charged with cold material. . . typically scrap steel.

- Scrap steel is first loaded into the electric arc furnace from an overhead crane. A lid containing three graphite electrodes is then lowered into the electric arc furnace. An electric current is passed through the electrodes to form an arc. The heat created from this arc then melts the scrap steel. Typically during the melting process, other metals are added to the steel to adjust for the required chemical composition. Oxygen is also blown into the furnace to purify the steel.

Step 4—Casting

- After achieving the required chemistry, molten steel is poured from a ladle into either a mold-casting operation to produce an ingot, or more often, into a continuous caster to produce a slab, billet, or bloom. During this process, the molten steel is typically cooled and transformed into a semi-solid state (solid on the outside, liquid on the inside). The resulting product is referred to as semi-finished.

- An ingot is simply a block of steel whose size can vary up to the size of a car, resulting from cooling of liquid steel inside a mold. Once obtained, the cast ingot can be reheated until the heat reaches a uniform temperature throughout the steel and processed further through re-rolling or breakdown into the common semi-finished shapes of slab, billet, or bloom.

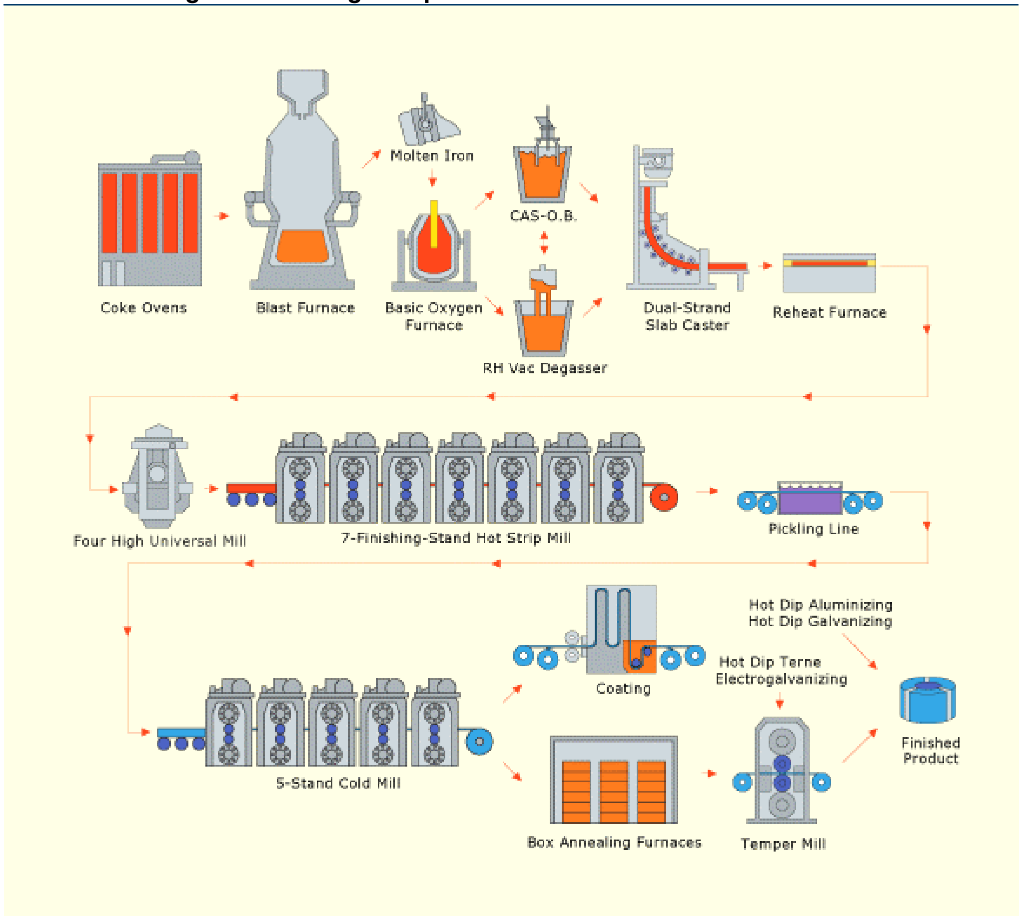
- A slab is the semi-finished product used to make flat rolled steel products, such as plate and sheet. Slabs have a rectangular cross section typically 4-12 inches thick and 3-5 feet across, though some reach widths of 10½ feet. A slab normally looks similar to a long mattress. Thin-slabs are only two inches thick. Slabs are then rolled (i.e., compressed), and transformed into flat products, either plate (rolled steel that is more than 3/16 of an inch thick) or sheet (rolled steel that is less than 3/16 of an inch thick). The benefit of starting with thinner slabs is it typically requires less rolling to reduce the required thinness; therefore, it is less expensive.

- A billet is the semi-finished product used to make long products, such as bar, rod, wire, rails, structural beams, and seamless pipe. Billets have a square cross section typically 2-6 inches on a side. A bloom is an oversized billet with a cross-sectional area greater than 36 square inches and is the typical semi-finished material for larger long products.

Step 5—Rolling and Finishing

- Depending on the specifications of the required finished product's end use, semi-finished products are further rolled or pinched into a finished product, either flat (i.e., sheet, plate, etc.) or long (i.e., rebar, beams, rails etc.).

Exhibit 4: Rolling and Finishing—Step 5



Source: AK Steel.

Types of Steel Products

Flat Rolled Products

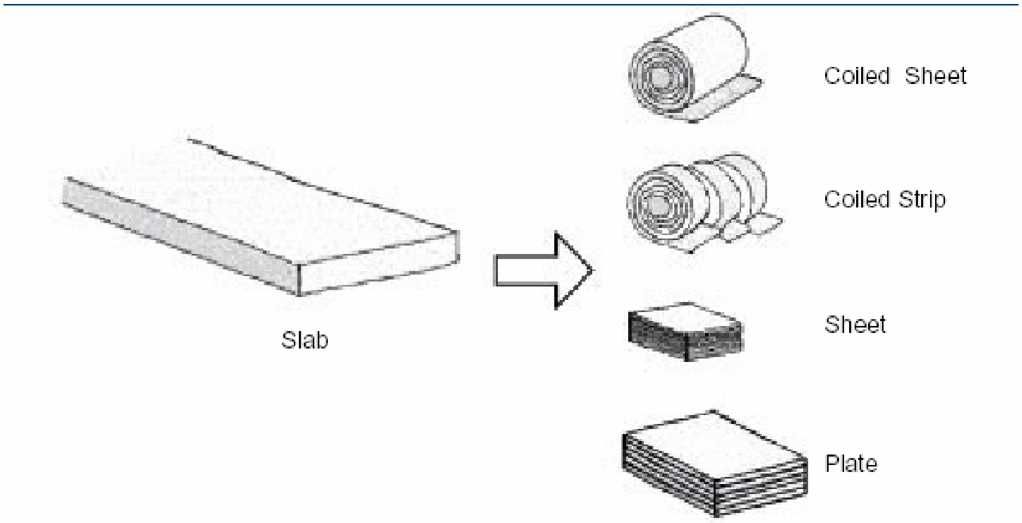
The hot rolling process is the reduction of slab thickness, after reheating and softening, through an enormous pressure applied by stands of rolls in the rolling mill (similar concept as rolling dough). The slab thickness can be reduced from 4-12 inches down to 0.10-2.00 inches, while its length can go from 30-40 feet up to one-half mile.

Scale breakers, descalers, roughers, or scarfers are the various types of machines used to prepare slabs for hot rolling by removing impurities on the slab as it moves through the rollers. After rolling, the hot rolled product can be coiled, or cut into sheets and plates.

The classification of flat rolled products into sheets and plates depends on the thickness of the product; usually, under 3/16 of an inch thick is considered sheet, while over 3/16 of an inch is classified as plate. A strip is a sheet that is less than 2 feet wide. Hot rolled coils represent the commodity grade product of semi-finished flat rolled steel.

Hot rolled products can be further processed into cold rolled products, coated or, formed and used for tubes and pipes production.

Exhibit 5: **Flat Rolled Products and Their Precursor Slab**



Source: VirtualSteel 2000.

Hot Rolled Coil (HRC)
Hot rolled steel can be shipped as it is (black band), cleaned and shipped (hot band), or rolled further into thinner gauges without reheating (cold rolled). Hot rolled steel is further cleaned in the pickling process, which cleans the surface of the steel by running the steel through an acid bath to remove the black oxide scale formed during the hot rolling process.

Cold Rolled Coil (CRC)
Cold rolled steel is a flat product in which the required final thickness is obtained by rolling the steel at room temperature. In cold rolling, the hot rolled coil is rolled into thinner gauges through further passage in rolling stands. Cold rolled steel possesses a better surface, enhanced strength, and better dimensional characteristics than hot rolled steel. While hot rolled steel typically has a thickness of 0.30-0.50 inches, cold rolled steel usually has a thickness of 0.08-0.13 inches.

Before processing into cold rolled steel, it is necessary to pickle the steel to eliminate the black oxide scale on the surface. The steel is then annealed, which involves slow heating and cooling to improve ductility.

Coated Steel
Applying a coating to steel significantly enhances the quality and/or appearance of certain types of steel. Coatings typically include zinc, aluminum, tin, terne, and paint.

Zinc Coating or Galvanizing
A layer of zinc can be put on steel by a hot dip or electrolytic bath. In the hot dip process the steel is immersed into a zinc bath until the desired coating of zinc is achieved. In the electrolytic galvanizing process an electric charge is put on the steel that bonds zinc to the steel's surface. Electro-galvanizing is more expensive than hot dip galvanizing; therefore, it has ceded market share to hot dip. Besides being less costly, hot dip galvanizing also provides a relatively greater degree of control over the zinc coating layers.

Typical applications for galvanized zinc are automobiles (underbody parts), air ductwork, roofing and siding, garbage cans, metal building panels, and metal studs (light), or electrical boxes, casings for light fixtures, bumpers, grain bins, and highway guard rails (heavy).

Tin-Coated Steel or Tinplate
A layer of tin can be applied to steel, typically via an electrolytic process. Tin mill products are used by the container industry in the manufacturing of cans, ends, and closures for the food and beverage industry because of their high corrosion resistance properties and ability to impart less metallic taste to food.

Terne-Coated Sheet
Terne-coated sheet is created by dipping steel in a bath of molten terne metal (a lead and tin alloy). Terne-coated sheet accounts for a relatively small portion of the overall steel market, but it has performance characteristics useful in applications, such as fuel tanks and air cleaners.

Painted Steel
Steel can also be painted, typically after applying a zinc or tin coating. Examples of painted steel applications include roofing, siding, gutters, interior cabinets, and appliances. Steel painting technology allows for more bending in painted steel without cracks and greater coating properties.

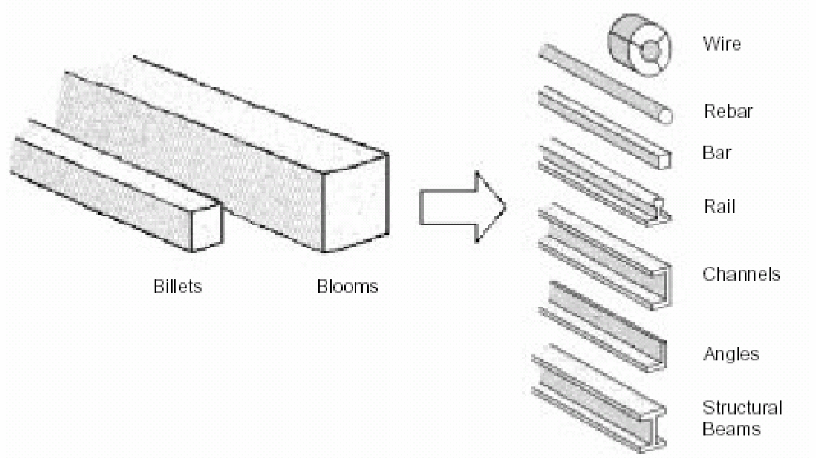
Plate
Plate products are hot-rolled products that are over 3/16 of an inch thick. Plates are used for ship building, construction, large diameter welded pipes, and boiler applications.

Flat Rolled Pipe and Tube Products
Pipes and tubes can be made from steel sheet or plate. A strip of steel is bent into a tube and welded lengthwise (or twisted into a continuous spiral and edge welded) to form welded pipe and welded tubing. An application for welded pipes includes standard plumbing. Electric-resistance welded (ERW) pipe, which is larger in diameter, is typically found in natural gas distribution lines.

Long Rolled Products

Long products are made by pushing billets and blooms through rollers that pinch and push the steel into different cross-sectional shapes. Finished output is typically bars, rails, structurals, rounds, angles, piling, channels, Z-angles, and hex shapes.

Exhibit 6: Long products and Their Precursors—Billets and Blooms



Source: VirtualSteel.

The four main categories of long products are rebar, merchant bar (MBQ), special bar quality bar (SBQ), and structurals.

Rebar

Rebar is a round bar with hash-mark indentations along the side and is primarily used for reinforcing concrete in construction and infrastructure applications. Rebar is more of a commodity than other bar products, making price the primary competitive factor. The majority of rebar in the United States is made from scrap via the mini-mill process.

Merchant Bar (MBQ)

Merchants include long bars with round, square, flat, angled, and channeled cross sections. Approximately 25% of the market is represented by joists, the largest end use for merchant shapes, 13% by other applications, 10% by mine bolts, and the remaining 50% includes a wide range of construction and industrial equipment, material handling, and transportation. Similar to rebar, merchant bar in the United States is primarily made from scrap via the mini-mill process.

Special Bar Quality (SBQ)

Bars with high and consistent metallurgical qualities are called SBQs. They are short diameter bars and are often used for making drawn wire. Applications may include motor shafts, engine bolts, screws, rivets, wrenches, bolts, springs, cable wire, chains, tire beads, and welding wire. Key industrial sectors for SBQ application are automotive, oil and gas, agricultural equipment, and capital goods.

Long-Rolled Pipe and Tube

Seamless pipe and tube is made by piercing a rotating heated bloom or billet with a long-armed, pointed piece of steel called a mandrel. Rollers can further work the pipe into a longer pipe with a shorter diameter.

Seamless tubing is used in process industries and boiler tubing. Special grades and longer diameters of pipe and tube go into oil country tubular goods (OCTG) and are necessary for down hole oil and gas drilling activity.

Specialty Steels

Specialty steels are defined by their alloy content, which changes the physical qualities of steel. For example, stainless steel, not only has carbon steel's qualities of strength, durability, and malleability, but also resists corrosion in many harsh environments, maintains its strength at high operating temperatures, and provides an attractive, easily maintained surface appearance.

Stainless Steel

Stainless steel is typically produced by melting stainless steel scrap in an electric arc furnace; therefore it is mini-mill based. The stainless steel production process is more batch-oriented than continuous-oriented when compared with typical carbon steel production process. The stainless steel market is a relatively small subset of the overall steel market representing approximately 2-3% of global steel output (by volume).

Stainless steel can be divided in Ferritic and Austenitic grades. Austenitic grades are the most commonly used stainless steels, accounting for more than 70% of global production of stainless steel. Austenitic grade stainless steel usually contains 4-35% nickel and 16-26% chromium. Austenitic grades have wider applications/uses than ferritic grades, but are more expensive to produce due to the higher nickel content. Austenitic grade stainless steel is typically used for applications, such as food processing equipment, flatware, kitchen sinks, and chemical plant equipment.

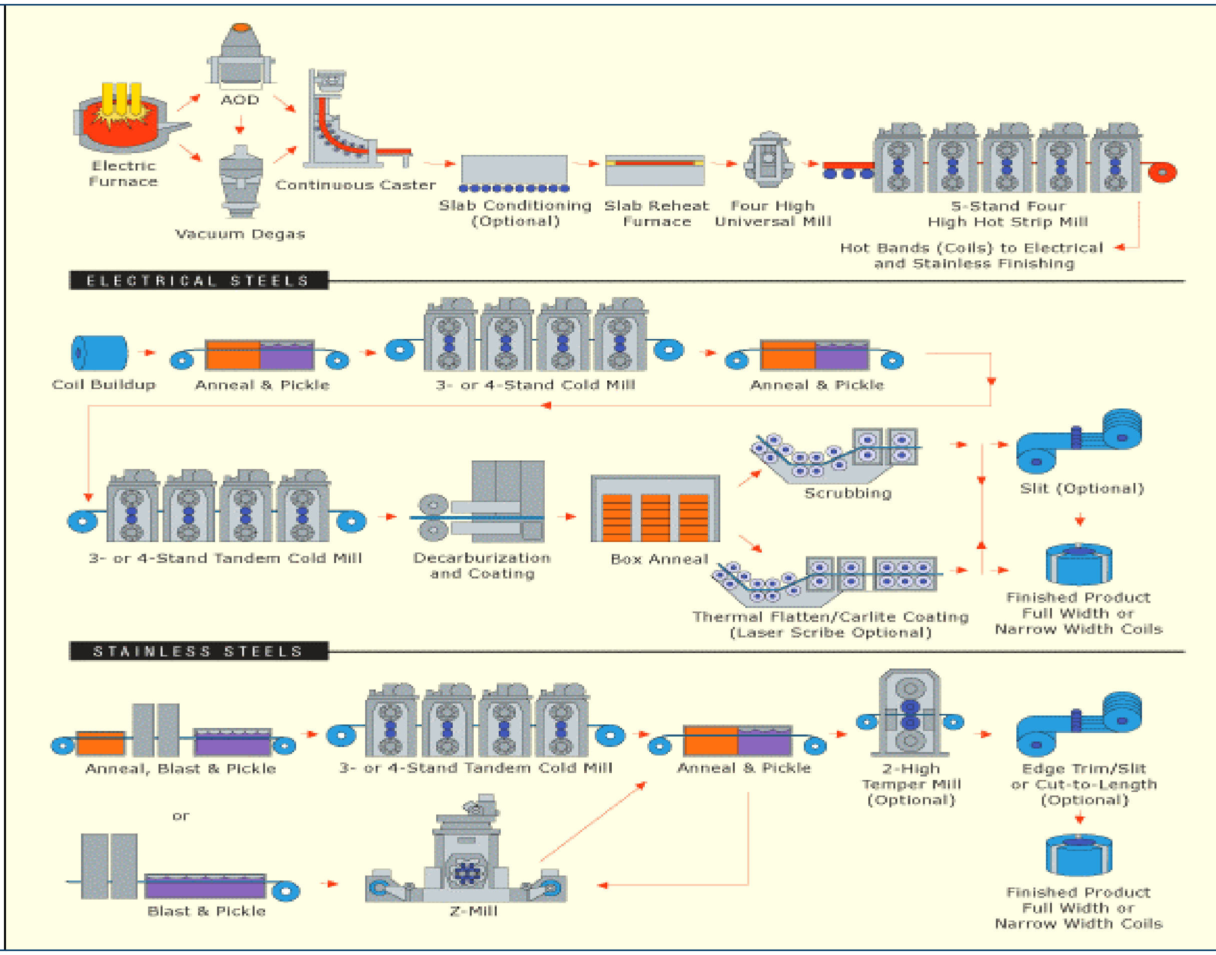
Ferritic Grade stainless steels typically contain 10-18% chromium and have no nickel content. Ferritic grade stainless is typically used for items, such as vehicle trim, auto exhausts systems, catalytic converters, and hot water tanks.

Electrical Steel

Electrical steel is also made by some producers of stainless steel. Electrical steel is classified as specialty steel owing to the absence of chrome. Electrical steel can be divided into grain-oriented (GO) and non-oriented. The former is treated in a way to align the atomic structure, which enhances conductivity and lowers resistance and heat generation. Grain-oriented steel is typically used in transformers both at power stations (25% of the GO market share) and distribution centers (50% market application) of the electric utility grid. GO demand is primarily dependant on housing starts and utility capital spending.

Non-oriented electric steel is electric steel where the atomic structure or grains are not necessarily aligned. Non-oriented electrical steel is mainly used in electric motors and appliances.

Exhibit 7: Stainless and Electrical Steel Production Flow Line



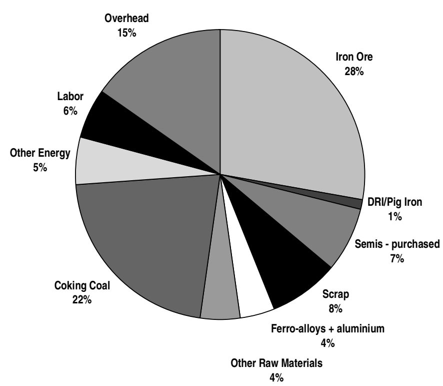
Source: AK Steel.

Components of Steel Costs

The cost of making steel depends on the production method used (integrated process versus mini-mill process). The integrated process utilizes less scrap, which results in higher quality steel, but typically is higher cost. Conversely, mini-mill production uses primarily scrap steel which translates into a relatively lower cost of production.

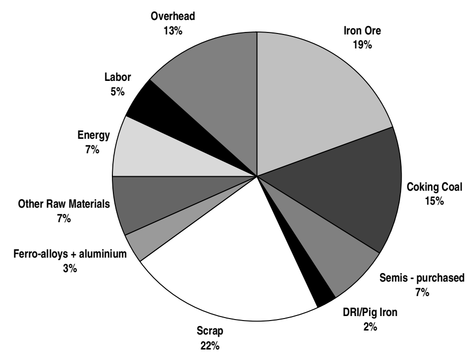
The two biggest components involved in producing steel via the integrated production process are iron ore and coking coal, which if taken together, comprise approximately 50% of total costs for standard hot rolled coil production. Conversely, for mini-mill producers, the single-largest cost component is scrap steel (20-50% of total), although iron ore and coking coal also represent a significant portion of total costs (i.e., approximately 20% in total).

Exhibit 8: Global Average Production Costs—HRC



Source: Metal Bulletin.

Exhibit 9: Global Average Production Costs—Bars



Source: Metal Bulletin.

Key Steelmaking Raw Materials

For the integrated production process, steel is created primarily by mixing of pig iron with steel scrap. One ton of pig iron is comprised of 1¾ tons of iron ore, ¾ ton of coke, ¼ ton of limestone, and 4 tons of air.

Iron Ore

Iron ore comprises roughly 5% of the earth's crust. Iron is the primary ingredient in the steelmaking process, with roughly 98% of all iron ore mined earmarked for steel making. Ores containing iron include Magnetite and Hematite, which contain roughly 70% and 72% iron. In the United States, iron is found in Taconite, which typically contains 30% Magnetite and Hematite, and can be concentrated to 60-70% iron content through a process of crushing and roasting, magnetic separation, or chemical/gravitational flotation. Concentrated iron ore is then formed into pellets, which are the most common form of processed iron ore used in steel making. Roughly 95% of usable ore (Taconite) in the United States comes from Michigan and Minnesota.

Coke

Coke is made by baking metallurgical coal in ovens at 1,650-2,000 degrees Fahrenheit. This process removes water and impurities in the coal to obtain an almost pure form of carbon that is lightweight but still structurally strong to avoid being crushed by the iron ore's weight in the blast furnace. The coke also becomes more porous, which enables proper airflow in the cooking section.

Limestone

Limestone is a key ingredient in step 2 of the pig iron process, and is continuously conveyed and poured, or charged together with coke and iron ore, into the top of the blast furnace. As the ingredients sift and sink to the bottom of the furnace, the heat breaks down the virgin iron ore, while the carbon monoxide attracts the oxygen from the iron oxide ore to form carbon dioxide, which exhausts. The residue is a purer iron material known as pig iron, which regroups in a liquid state at the bottom of the furnace.

In the lower portion of the blast furnace, molten limestone attracts other impurities in the cooking ore and floats them on the bath of molten pig iron forming in the bottom of the furnace. The limestone layer is called slag, which attracts certain elements and repels others, as those elements precipitate out of the molten solution.

Scrap Steel

Scrap is required by both integrated and mini-mill steel producers. It is the primary input for mini-mills, and accounts for approximately 10-40% of the basic oxygen furnace inputs in the integrated process. While there are no direct substitutes for iron ore in the integrated process, in times when scrap prices are low, integrated producers will try to use more scrap in place of iron ore to reduce costs.

Scrap steel supply/demand is typically effected by similar supply/demand drivers of finished steel, although scrap steel has its own individual supply/demand (and hence pricing) patterns. Also, because scrap can act as a substitute for iron ore, the prices of the two commodities generally move in the same direction.

Scrap can be classified in two different grades.

Low Residual Scrap

Low residual scrap can be classified in five different grades. No.1 bushlings are steel scrap of any dimension under one foot. They include sheet clippings and stampings, and typically result from waste trim material from steel product fabrication. Low residual scrap steel does not include old auto stock or coated material. Black sheet clippings are basically waste originated by hot rolled material processing, no longer than 8 feet by 18 inches. No.1 bundles are compressed scrap or hand bundled, including chemically detinned material. Shredded clippings consist of scrap cut into smaller pieces, and include recovered steel from automobiles, unprepared No. 1 steel, and miscellaneous scrap.

Home scrap is the last source of lower residual scrap and is internally generated by a steel company and includes side trim, end trim, and poor-quality production recycled back into the melt system.

Obsolete Scrap

Obsolete scrap comes from a variety of peddlers, auto dismantlers, and minor smaller machine shops as well as railroads, demolition projects, and shipyards. The different obsolete scrap steel production processes include shredding, chopping, or bundling.

Scrap Substitutes and New Technologies

Direct Reduced Iron (DRI)

Direct reduced iron is the creation of iron from iron ore via heating and chemical reduction by natural gas, as opposed to in a blast furnace. Direct reduced iron is typically more expensive than reducing iron ore in a blast furnace, but at the same time it is richer in iron than pig iron (i.e., 97% pure iron versus 93% for molten pig iron). For a mini-mill, DRI serves as a feedstock allowing the mini-mill to use lower grades of scrap steel for the remaining portion of the steel production inputs.

Circofer and Circored

Circofer and Circored are reduced-iron processes that utilize fluidized bed reactors to reduce iron ore fines. Coal is the fuel needed for the Circofer process, while Circored utilizes natural gas.

Corex

The Corex process combines an iron melter/coal gasifier vessel with a prereduction shaft to produce a liquid product that is very similar to blast furnace hot metal. Coal, oxygen, and prereduced iron are fed into the melter/gasifier to melt the iron and produce a highly reduced-gas.

Fastmet

The fast-metalization process forms pellets from iron ore fines and pulverized coal. The process is fast, as pellets are transformed into metallic ore in a few minutes through placement in a rotary hearth furnace that dries them up and reduce them into metal for 90-95%.

The advantage is that this process uses cheaper coal instead of natural gas, while the drawback is that a lot of attention has to be paid while shipping the material, as it is very sensitive to water (it can burn due to its instability) and because it contains more sulfur and phosphorus when compared with standard reduced iron products.

Iron Dynamics

The iron dynamics (IDI) process implies the formation of a cake of coal and iron ore fines, which is subsequently passed through a rotary hearth. Although this process is fast (it can be completed in a few minutes), it too contains more sulfur, which is removed through another cooking step in a customized arc furnace that is electric energy based.

Iron Carbide

This process directly reduces iron by using hydrogen and natural gas, instead of coal. The iron carbide system extracts oxygen and impurities from the ore and leaves iron and carbon. The outcome is 80-90% iron carbide (Fe_3C), which contains 8% carbon. Iron carbide is stable enough for shipping, and does not need to be formed into pellets. The extra carbon contained in iron carbide can be used to produce heat in the arc furnace, which reduces electricity needs. Iron carbide could also replace up to 25% of the scrap input in an electric furnace, although it would be necessary to install additional injection equipment.

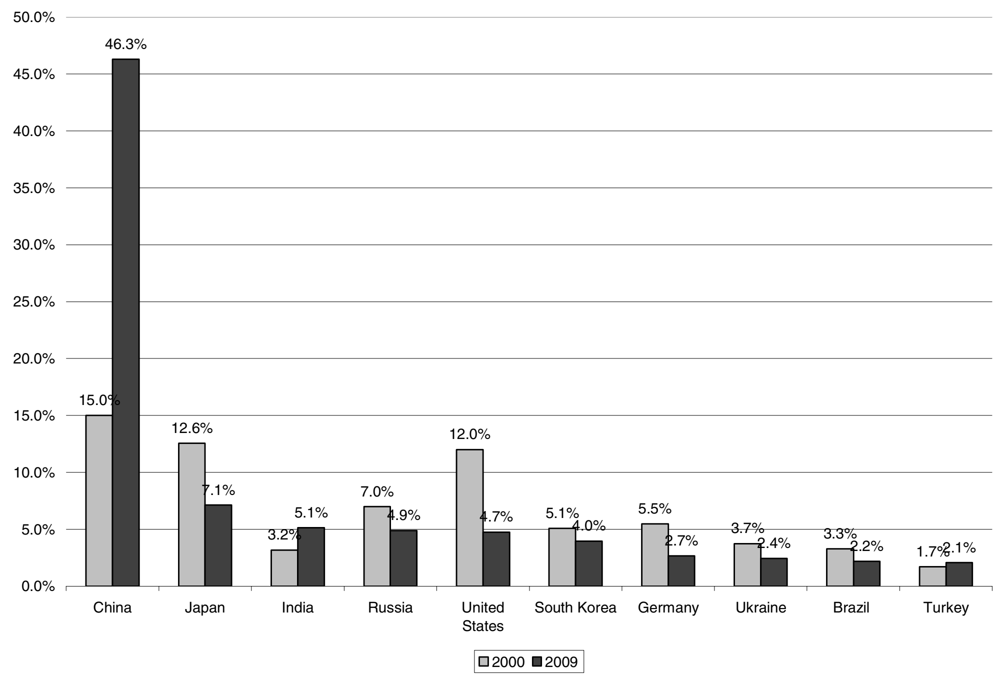
Other

Other processes include DIOS (two-stage furnace, coal based, uses fines, Japan); Hismelt (shaft furnace, coal based, uses fines); HYL (shaft furnace, natural gas based, pellets or lump ore, Hylsa); Inmetco (natural-gas-fired rotary hearth furnace, pelletized iron ore with coal, Inco); Midrex (shaft furnace, natural gas based, pellets or lump ore); Purofer (shaft furnace, natural gas, lump ore, Thyssen-Hutte); and SL/RN (tilted rotary hearth furnace, coal based, lump ore or pellets, international joint venture).

Sources of Supply

Geographically, the emergence of China as the driver of industrial growth in the past decade has resulted in significant demand and production growth. China's market share of global crude steel production increased to 46.3% in 2009 from 15.0% in 2000.

Exhibit 10: Top Global Steel Producers by Country (Percent of Total Production)



Source: World Steel Association.

In terms of individual producers, as of year-end 2009, the steel industry was still fragmented, with the twenty largest global players controlling approximately 34% of global crude steel production. By way of comparison, the top ten copper producers in 2010 controlled approximately 50% of global mine supplies.

Exhibit 11: Top Twenty Global Steel Producers (Based on 2009 Output)

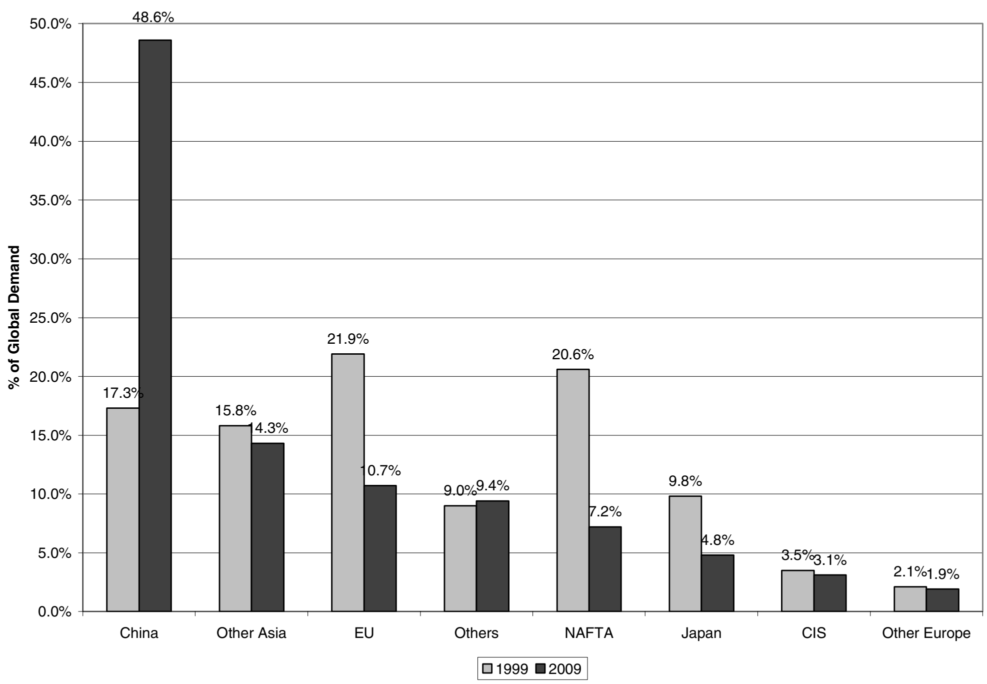
Company	Production	% of Global Production
ArcelorMittal	77.5	6.32%
Baosteel	31.3	2.55%
POSCO	31.1	2.53%
Nippon Steel	26.5	2.16%
JFE	25.8	2.10%
Jiangsu Shagang	20.5	1.67%
Tata Steel	20.5	1.67%
Ansteel	20.1	1.64%
Severstal	16.7	1.36%
Evraz	15.3	1.25%
US Steel	15.2	1.24%
Shougang	15.1	1.23%
Gerdau Group	14.2	1.16%
Nucor	14.0	1.14%
Wuhan	13.7	1.12%
SAIL	13.5	1.10%
Handan	12.0	0.98%
Riva	11.3	0.92%
Sumitomo	11.0	0.90%
ThyssenKrupp	11.0	0.90%
Total	**416.3**	**33.93%**

In million metric tons. Source: World Steel Association.

Steel Demand

Similar to global steel production trends, steel consumption on a global basis has shifted from North America and Europe to Asia, specifically China. China's share of global steel consumption has increased from approximately 17% in 1999 to almost 50% as of 2009. Meanwhile, NAFTA and Europe's combined share of steel demand declined from almost 43% to 17% during the same period.

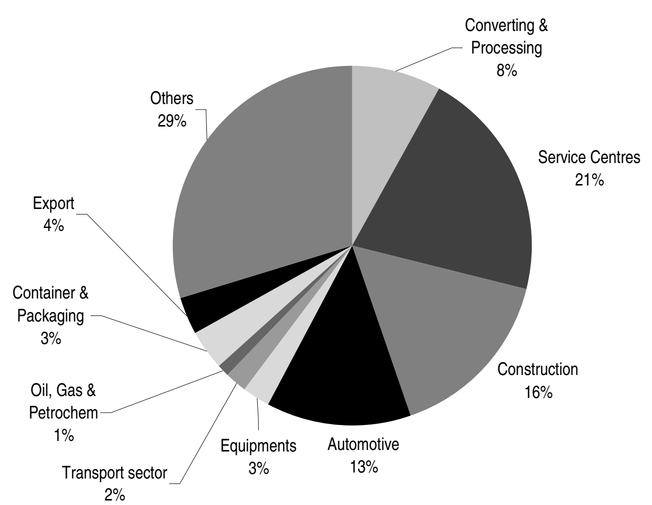
Exhibit 12: Global Apparent Steel Consumption



Source: World Steel Association.

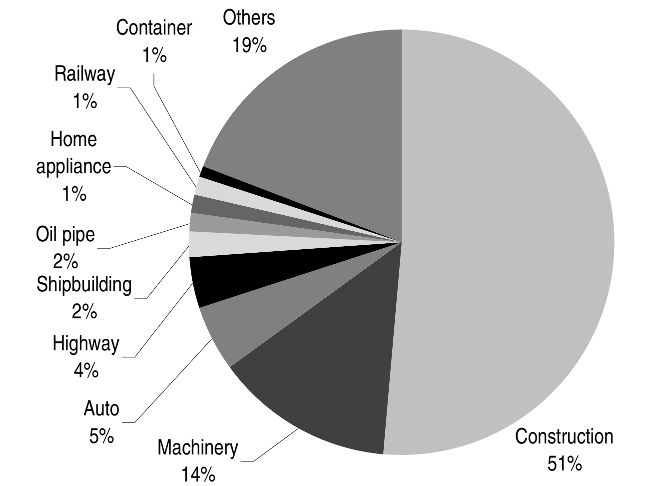
Depending on the country, overall steel demand can vary widely by end market. For example, construction sector consumption of steel in the United States and Japan accounts for approximately 16% and 17% of total steel demand, respectively, whereas the construction sector accounts for over 50% of steel demand in China and 64% in India. In general, developing countries typically have a higher concentration of end-market consumption in construction related applications, whereas developed countries consume steel across a broader base of end-markets.

Exhibit 13: Steel Demand by End Market—USA



Source: AISI, Credit Suisse estimates.

Exhibit 14: Steel Demand by End Market—China



Source: CBI, Credit Suisse estimates.

Steel Service Centers

In the United States, service centers represent the largest end-market customer of the steel producers, accounting for 20-25% of total carbon, alloy, stainless, and specialty steel shipments. Steel service centers represent the middle man in the steel supply chain, providing a conduit between the integrated and mini-mill steel producers and smaller scale industrial steel consumers, such as steel fabricators, original equipment manufacturers (OEMs), auto parts makers, construction, electronics, energy, and virtually every other general purpose industrial application that uses steel. With over 3,500 steel service centers in the United States, and only 8 of the 20 largest steel service centers are public companies, the service center industry is a highly fragmented sector relative to the steel producers.

Globally, service centers fill a similar role in the supply chain; however, the ownership structure varies greatly by country. Service centers in many regions are owned and operated by the upstream steel producers and are not independent companies, such as those in the United States. Additionally, while Europe and Brazil are roughly similar to the United States in terms of percent of steel which flows through service centers (i.e., 20-25%), in China almost one-half (approximately 46%) of all steel shipments flow through a highly fragmented service center industry.

Service centers typically work with smaller customer orders, storing materials, and delivering non-standard shapes and small order sizes to a broad customer base that the primary steel producers could or would not service. The industry consists of both general-line distributors that handle a wide range of metal products; commodity grade distributors that simply buy the material from the producer, store it as is and then distribute it to a customer when requested (i.e., no value-added services); and specialty distributors that specialize in certain categories of metal products, and then tailor the product to the specific metallurgical (i.e., pickling, galvanizing, slitting, etc.) or size requirements of the customer prior to shipment. In addition to steel, some service centers provide the above services for a variety of metals, including aluminum, copper, brass, and superalloys.

Service centers also provide tolling services to the steel producers, particularly during periods of high steel demand that result in a lack of available capacity for these services within the steel producers' own facilities. Most industry participants have a carbon and stainless product mix that is either more heavily weighted toward flat products (i.e., sheet and plate) or long products (i.e., bar and tube), as well as non-ferrous products, such as aluminum ingot, copper, and other minor metals, such as chromium, copper, zinc, etc.

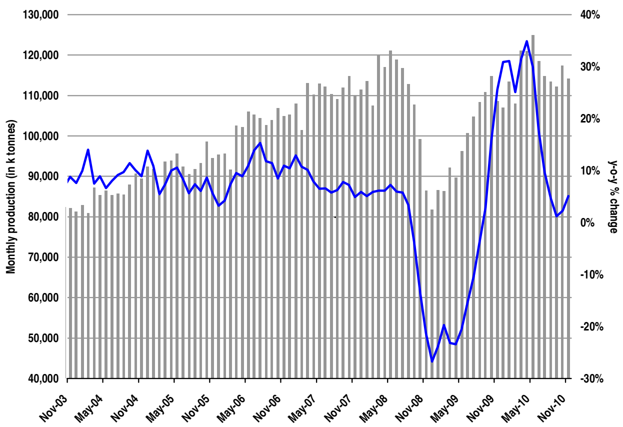
U.S. & Global Datapoints to Watch

Global Crude Steel Production

Global crude steel production data is compiled by the World Steel Association (formerly IISI) on a monthly basis, typically released between the 18th and 22nd of each month.

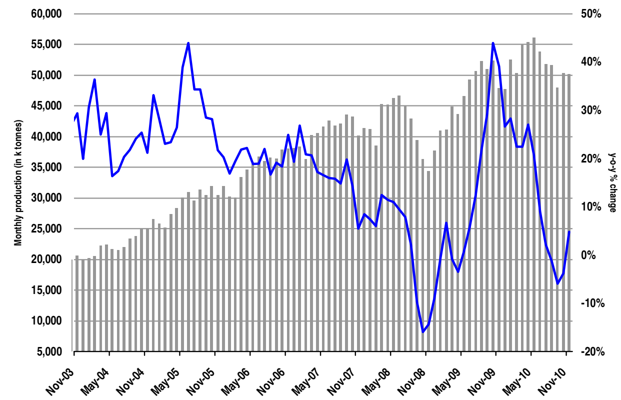
With the exception of 2008 and 2009, global production rates have increased significantly over the past decade, led by massive increases in Chinese production.

Exhibit 15: Global Crude Steel Production



Source: World Steel Association.

Exhibit 16: Chinese Crude Steel Production



Source: World Steel Association.

Monthly U.S. Service Center Data

As mentioned above, service centers comprise roughly 20% of total steel purchases in the United States, and act as the middle man in the steel supply chain; because they make up a fairly large percent of the market, service centers are a good proxy for the current state of steel demand as well as the state of the steel supply chain (i.e., inventory levels).

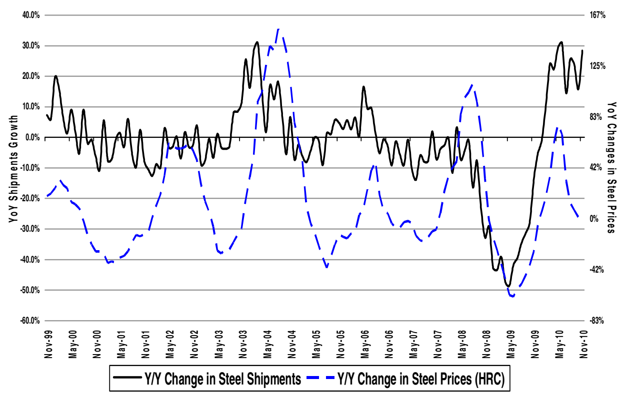
In the United States, monthly data is provided by the Metals Service Center Institute (MSCI) pertaining to both absolute steel inventories (i.e., the tons of steel held at the U.S. service centers) and shipments from the service centers to the end market customers. The data is typically released during the third week of every month.

The months of available supply is derived by dividing absolute inventories by monthly shipments.

General Rules of Thumb for Months of Supply:

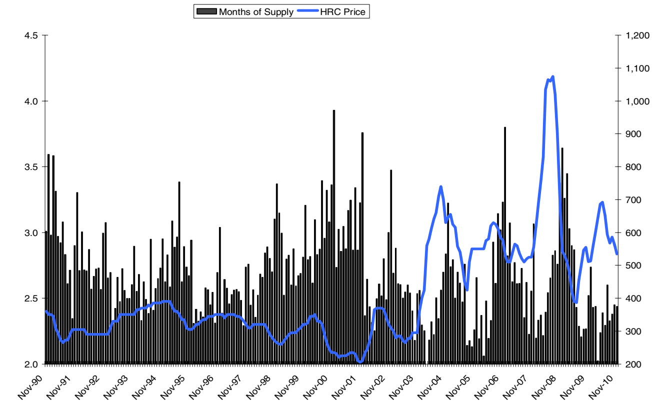
- Below 2.5 months of supply = low inventories, potential for price increases.
- 2.5 months of supply = normal inventories.
- 2.5-3.0 months of supply = high inventories, although pricing generally stable.
- Above 3.0 months of supply = surplus inventories; destocking required; increased risk of price weakness ahead.

Exhibit 17: Steel Prices versus Service Center Shipments (Year-over-Year Percentage Change)



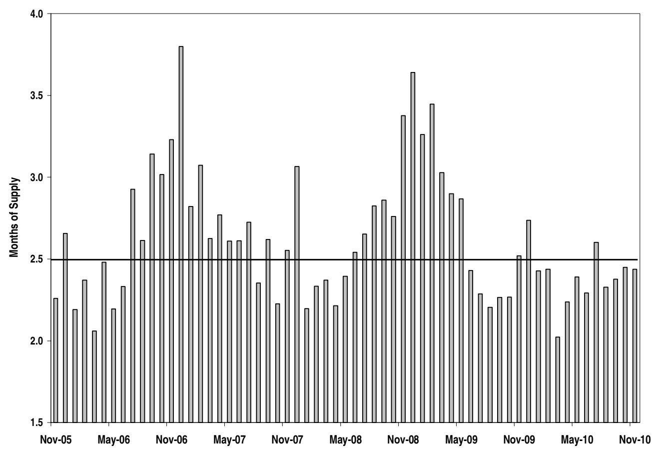
Source: Metals Service Center Institute, CRU.

Exhibit 18: Months of Supply versus HRC Prices



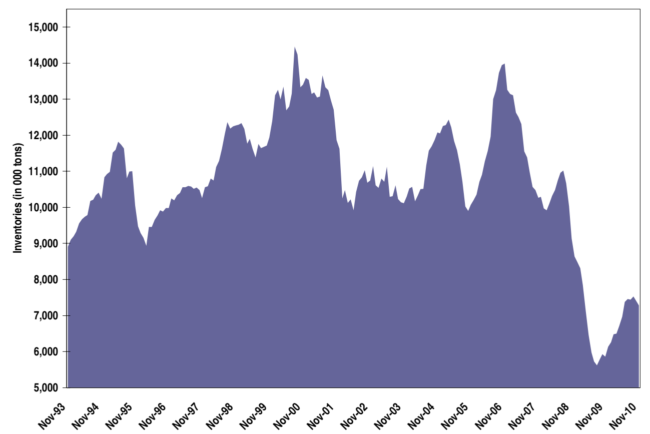
Source: MSCI, CRU, Credit Suisse estimates.

Exhibit 19: Months of Supply (Monthly)



Source: Metals Service Center Institute.

Exhibit 20: Absolute Inventories (Monthly)



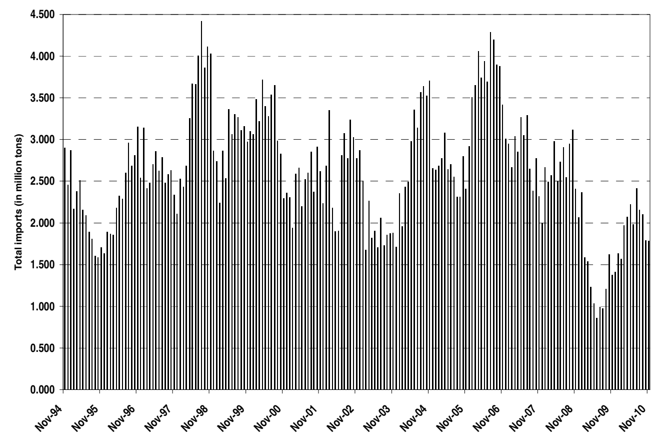
Source: Metals Service Center Institute.

U.S. Steel Imports

Another significant component of U.S. steel supplies is imported steel. The United States is a net importer of approximately 20-30% of total consumption needs. U.S. steel imports are reported by the U.S. Department of Commerce on a monthly basis, with preliminary U.S. import data typically released during the last week of each month, with final data released approximately two weeks later.

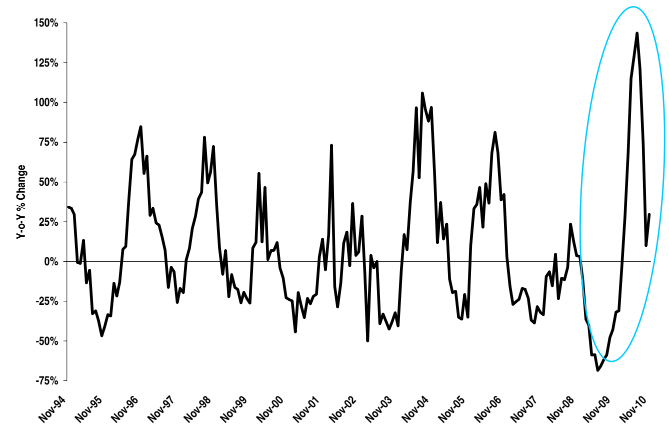
Preliminary import license data is also compiled by the US Department of Commerce on a cumulative basis throughout the month and updated on a weekly basis, and in general provides a more timely indication of monthly import trends during the current month.

Exhibit 21: U.S. Import Data (Monthly)



Source: U.S. Dept of Commerce.

Exhibit 22: Year-over-Year Change in U.S. Imports



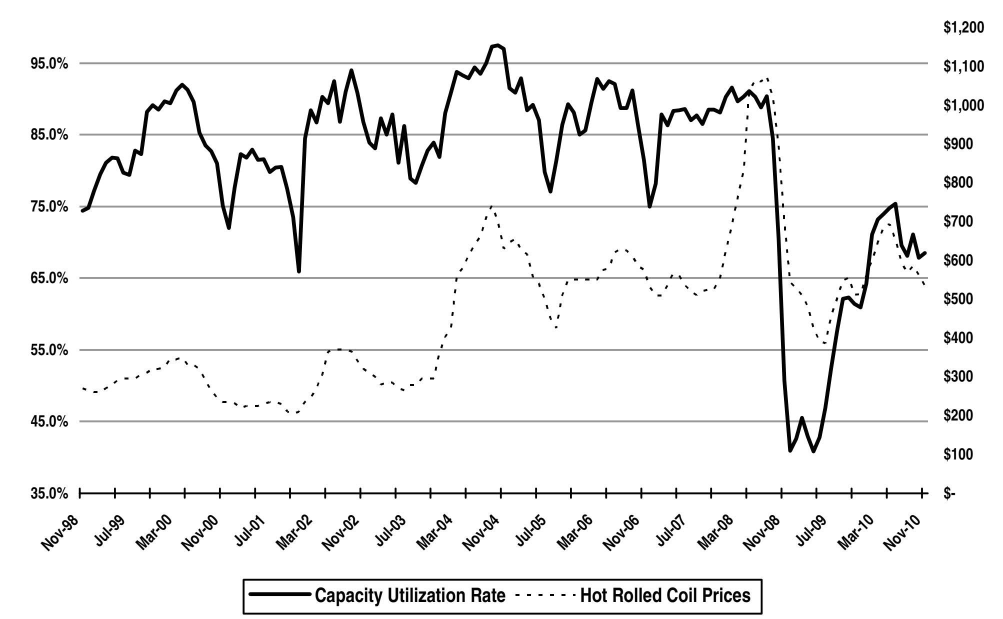
Source: U.S. Dept of Commerce.

U.S. Capacity Utilization Rates

Given the highly cyclical nature of steel consumption, one useful barometer to gauge near-term consumption trends in the United States is capacity utilization rates, or the average percentage of available capacity currently in use for steel production. Capacity utilization rates are reported by the American Iron and Steel Institute (AISI) on a weekly basis. Typically, capacity utilization rates range between 75-90%. In periods of exceptionally strong demand, utilization rates have approached 95%, and in periods of exceptionally weak demand, utilization rates have dipped below 45%.

Historically, there has been a positive correlations between U.S. capacity utilization rates and U.S. hot rolled coil prices. (See Exhibit 23.)

Exhibit 23: Capacity Utilization Rates versus HRC Prices



Source: American Iron & Steel Institute, CRU.

Companies Mentioned *(Price as of 12 Jan 11)*
Allegheny Technologies Inc. (ATI, $58.64)
ArcelorMittal (MT.N, $35.18, OUTPERFORM [V], TP $49.00, OVERWEIGHT)
Baoshan Iron & Steel (600019.SS, Rmb6.77, OUTPERFORM, TP Rmb10.20)
Evraz Group SA (HK1q.L, $41.18, OUTPERFORM [V], TP $45.00)
Gerdau (GGBR4, R$24.73, OUTPERFORM, TP R$31.00)
JFE Holdings Inc (5411, ¥2,906, OUTPERFORM, TP ¥3,500, OVERWEIGHT)
Nippon Steel (5401, ¥302, OUTPERFORM, TP ¥350, OVERWEIGHT)
Nucor (NUE, $44.73, OUTPERFORM, TP $52.00)
POSCO (005490.KS, W481,000, OUTPERFORM, TP W675,000)
Severstal (CHMFq.L, $19.04, OUTPERFORM [V], TP $20.00)
Sumitomo Metal Mining (5713, ¥1,412, OUTPERFORM, TP ¥1,500, OVERWEIGHT)
Tata Steel Ltd (TISC.BO, Rs647.70, UNDERPERFORM [V], TP Rs525.00)
Thyssen Krupp AG (TKAG.F, Eu31.84, OUTPERFORM [V], TP Eu35.00, OVERWEIGHT)
United States Steel Group (X, $56.63, NEUTRAL [V], TP $55.00)
Wuhan Iron & Steel Co. Ltd (600005.SS, Rmb4.41, NEUTRAL [V], TP Rmb7.00)

Disclosure Appendix

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***An analyst's coverage universe consists of all companies covered by the analyst within the relevant sector.*

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Market Weight: Industry expected to perform in-line with the relevant broad market benchmark over the next 12 months.

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Restricted	2%	

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